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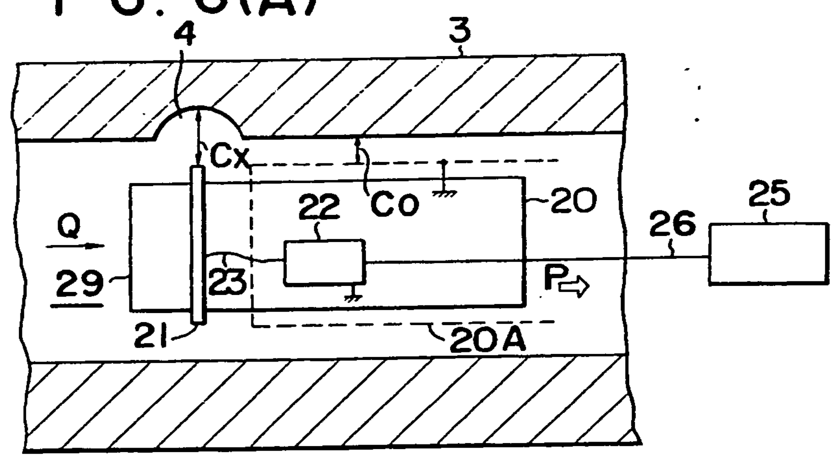
(71) Applicant
Koa Oil Company Limited,
6-2, Ohte-Machi 2-
Chome, Chiyoda-ku,
Tokyo-To, Japan
(72) Inventor
Okiyoshi Okamura
(74) Agent
Elkington and Fife

(54) Detecting Capacitively Corrosion of Pipes

(57) Most of the pipes or the tubes used in the field of chemical industry such as petroleum industry are in corrosive atmosphere. The presence or absence and degree of corrosion damage in such a pipe 3 is detected and measured by using a probe which forms a capacitor with the inner wall of the pipe. The probe may comprise an insulating member 20 carrying conductive ring 21, the capacitance C_x between the ring and pipe being measured by connecting them in a bridge circuit or a resonant circuit. Alternatively the major part of the probe may be shielded 20A and the series circuit of the constant stray capacitance C_0 and capacitance C_x connected in the bridge circuit. Ring 21 may be replaced by a plurality of conductive segments each connected to a capacitance measuring circuit or the segments may be used in addition to the ring.

F I G. 6(A)



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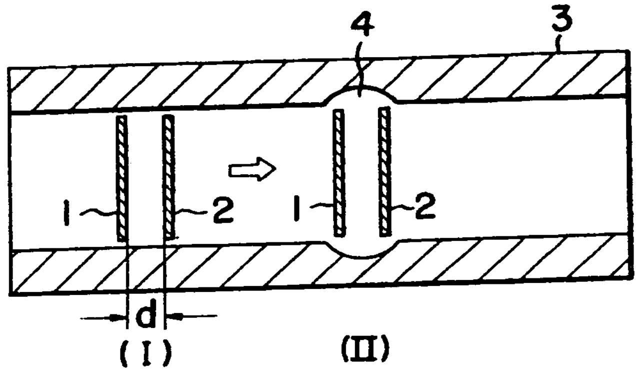
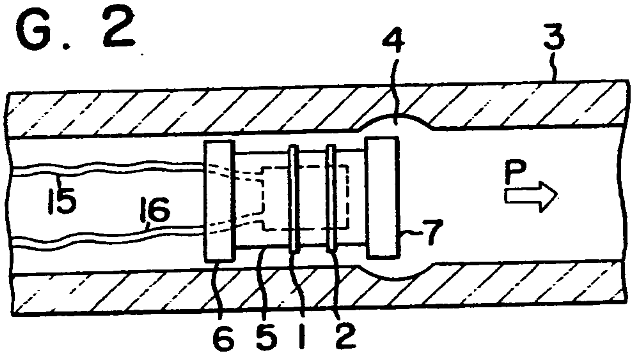
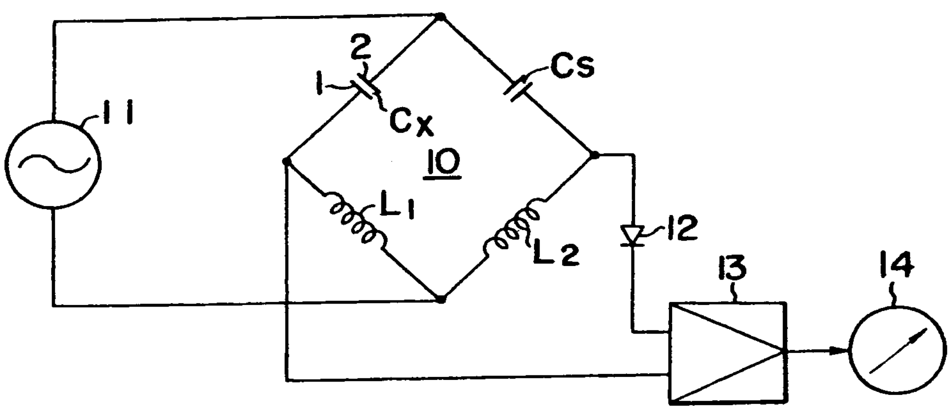
F I G. 1



F I G. 2



F I G. 3



F I G. 4

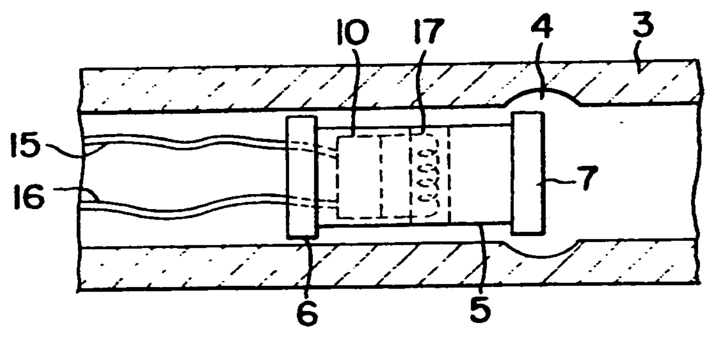


FIG. 5

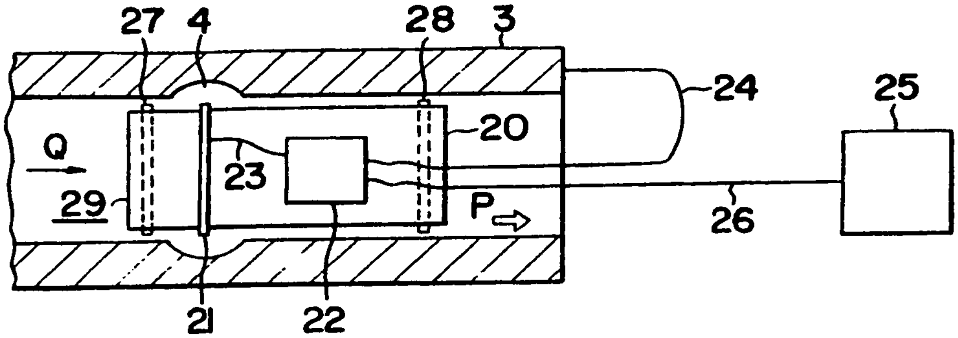


FIG. 6(A)

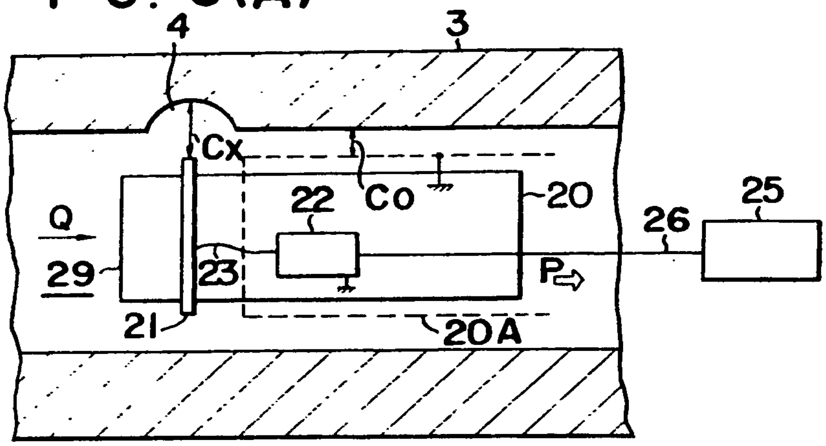


FIG. 6(B)

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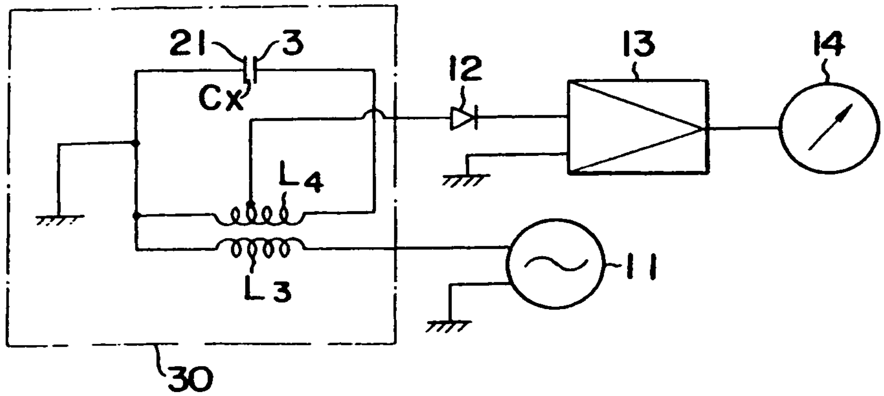
FIG. 7



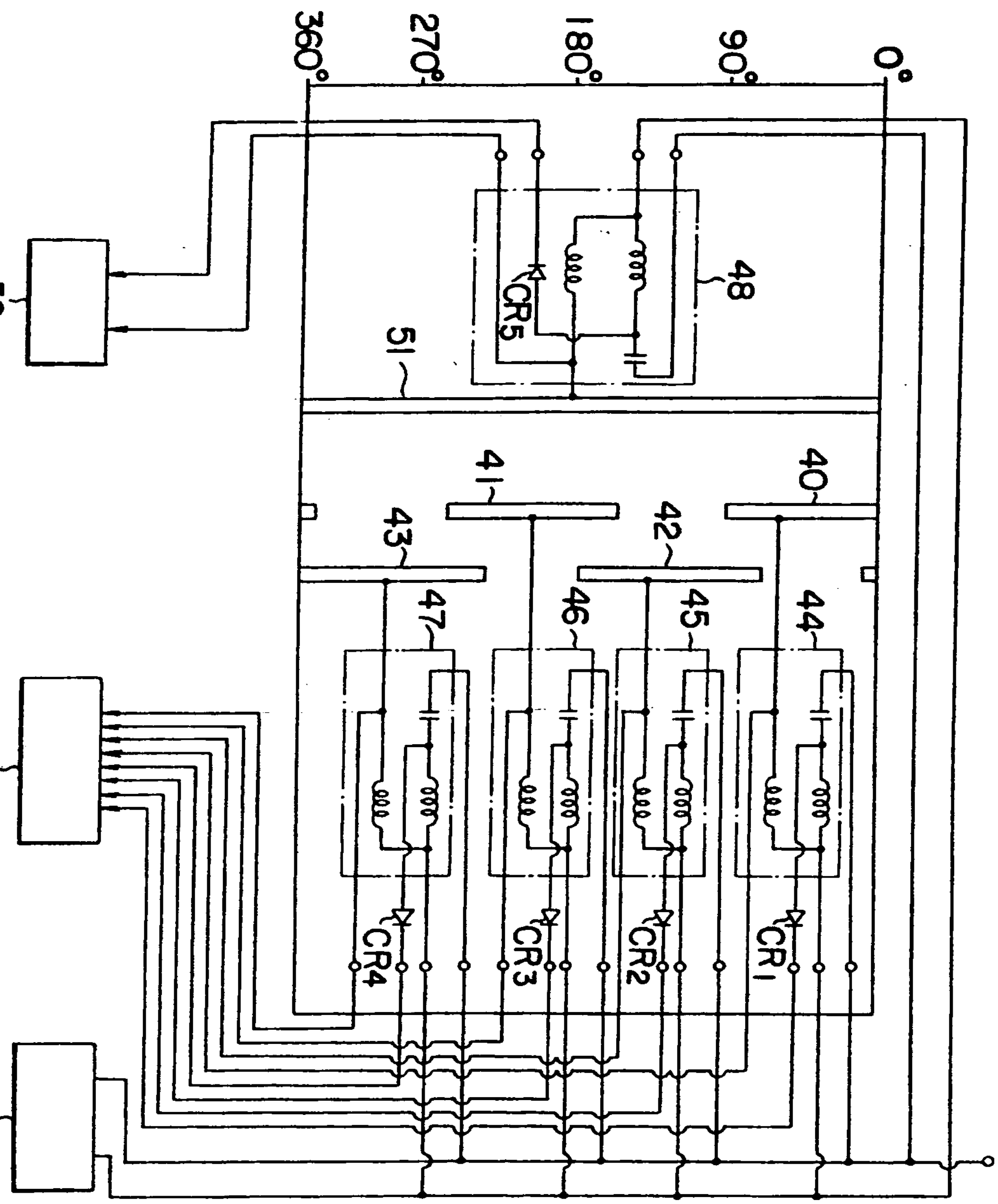

0°
90°
180°
270°
360°
40
41
42
43
44
45
46
47
48
49
50
51
52
CR1
CR2
CR3
CR4
CR5

FIG. 8

SPECIFICATION

Method and Apparatus for Detecting the Degree of Corrosion Damage

This invention relates to a method and apparatus for detecting the degree of corrosion damage, and more particularly to detecting the presence or absence, position and degree of corrosion damage in a hollow pipe such as a pipe or a tube used in a heat exchanger.

In the filed of chemical industry, for example in petroleum refining, a variety of heat exchangers having a number of pipes or tubes (hereinafter, referred to as "pipes") are used. Most of these pipes are in corrosive atmosphere. It is therefore absolutely necessary to inspect them for integrity and service life.

One known system for detecting the degree of corrosion damage in such a pipe is a so-called eddy current type flaw detecting system which is extensively employed for austenite stainless steel pipes and brass pipes. In this system, an exciting coil and a detecting coil are used, and flaws in a pipe are detected according to a pulse signal emitted by the detecting coil or variations in the impedance thereof. However, this system has some disadvantages. The output signal does not correspond to the depth of a portion damaged by corrosion (hereinafter referred to merely as "a corrosion portion" when applicable), and accordingly the detection accuracy is limited. In addition, the pipe being inspected must be of non-magnetic material, and accordingly magnetic saturation must be employed for inspecting a magnetic pipe such as a steel pipe.

Another known system of measuring the wall thickness of a pipe uses radiant rays. However, this system is also disadvantageous in that the measurement must be carried out in one direction only, and it is impossible to measure completely pipes which are bundled. In addition, a fibre-scope method has recently been employed to observe the inside of a pipe. However, this method is low in efficiency, and it is liable to miss corrosion portions.

In view of the foregoing, the following method has been employed to detect more positively the degree of corrosion damage in a pipe. For instance, in inspecting the pipes of a heat exchanger (which has a number of pipes), a single typical pipe is removed from the heat exchanger, and is inspected by destructive testing damage, and the corrosion damage to the remaining pipes is estimated on that basis. However, it is apparent that such a method is low in efficiency and is not economical. A method of measuring the wall thickness of a pipe with ultrasonic waves and a method of directly measuring a flaw with a depth gauge are known in the art. However, both of the methods are inefficient and cannot be used to carry out high accuracy measurement.

Another system for detecting the degree of corrosion damage is shown in Figs. 1 to 3 of the accompanying drawings. In this system electrical conductive discs 1 and 2 are disposed in such a manner that they are perpendicular to the axis of a pipe 3 to be inspected and the circumferential surfaces thereof are adjacent the inner wall to the pipe 3. The discs are held by a cylinder member 5 made of an insulating material, so that they can be moved in the longitudinal direction of the pipe with the distance *d* between the discs 1 and 2 being maintained constant. The discs 1 and 2 are moved from the position (I) to the position (II). In this case, rings 6 and 7 each of which has an outside diameter which is larger than those of the discs 1 and 2 but smaller than the inside diameter of the pipe 3 are placed over the two end portions of the cylinder member 5 as shown in Fig. 2, and compressed air is supplied into the pipe 3 so as to move the discs 1 and 2, for instance in the direction P.

When the discs 1 and 2 are charged to opposite polarities (positive and negative), none of the electric lines of force between the discs is straight, that is, they are curved in the vicinity of the edges of the discs. In this connection, the dielectric constant at the position (I) where no damage is different from that at the position (II) where a corrosion portion 4 exists because the inside diameter of the pipe at the position (I) is different from that at the position (II). Accordingly, the static capacitance Cx between the discs 1 and 2 at the position (I) is different from that at the position (II). Therefore, the degree of corrosion damage can be detected by a method in which, as shown in Fig. 3, a bridge circuit 10 is formed with the discs 1 and 2, a high frequency voltage is applied to the bridge circuit 10 by a high frequency (144 MHz for instance) oscillator 11, the resulting unbalance voltage is rectified by a rectifying diode 12, and the output of the diode 12 is amplified by an amplifier 13 and is displayed on a voltmeter 14.

If the values of a reference capacitor Cs or reference inductance coils L_1 and L_2 or the bridge circuit 10 are so selected that the output of the bridge 10 is minimum when the discs are at the position (I), when the discs 1 and 2 is moved to the corrosion portion 4, the capacitance Cx is changed and the unbalance output of the bridge circuit 10 is increased. In this case, the degree of variation of the output corresponds to the degree of corrosion damage. Therefore, if an analytic curve is determined from reference pipes in advance, the degree of corrosion damage can be obtained.

In Figs. 2 and 3, reference numeral 15 designates a lead wire, or a coaxial cable, connected to the oscillator 11, and reference numeral 16 designates a lead wire connected between the amplifier 13 and the bridge circuit 10.

Fig. 4 of the accompanying drawings shows another known detecting device. An inductance coil 17 is provided instead of the capacitance between the discs. In this case, the degree of corrosion damage is detected by utilizing the phenomenon that the coil inductance is changed by variations in magnetic permeability which are caused by the presence and absence of a

corrosion portion 4. The coil 17 is employed as a part of the bridge circuit 10, similarly as in the above-described case.

An object of this invention is to provide a detecting system which is most suitable for detecting the presence or absence, position and degree of corrosion damage in the inner wall of a hollow pipe, and a device for practicing the system, and further to provide a detecting system by which the presence or absence, position and degree of corrosion in the inner wall of a hollow pipe can be positively detected with relatively simple arrangement.

According to the invention there is provided a method of detecting the degree of corrosion damage, in which a member made of an insulating material and having an outside diameter slightly smaller than the inside diameter of a pipe to be inspected is provided, the said member being circular in section and having an electrical conductor mounted on the outer wall thereof, and the said member is moved in the pipe in the longitudinal direction thereof to detect a state of corrosion damage in the inner wall of said pipe from variations in capacitance between the electrical conductor and the pipe which are caused by the movement of the said member in the pipe.

In the accompanying drawings:

Fig. 1 is an explanatory diagram of a known system of detecting the degree of corrosion damage;

Fig. 2 and Fig. 4 are diagrams each showing one example of a known device of detecting the degree of corrosion damage;

Fig. 3 is a diagram showing one example of a known detecting circuit for use with the device of Fig. 2.

Fig. 5 is an explanatory diagram showing one example of a device for detecting the degree of corrosion damage according to this invention;

Fig. 6(A) is an explanatory diagram showing one concrete example of the device according to the invention;

Fig. 6(B) is an equivalent circuit of the device shown in Fig. 6(A);

Fig. 7 is a schematic circuit diagram (partly as a block diagram) showing one example of a detecting circuit exployed in the invention; and

Fig. 8 is a schematic circuit diagram showing one modification of the device to the invention.

Fig. 5 shows a cylinder member 20 made of an insulating material and having an outside diameter smaller than the inside diameter of a pipe 3, a ring 21 which is made of an electrically conductive material and is fixedly secured around the outer wall of the cylinder member 20, and a bridge circuit 22 as shown in Fig. 3 which is incorporated by moulding in the cylinder member 20. Instead of the bridge circuit 22, a resonance circuit as shown in Fig. 6 may be employed. A lead wire 24 connects the bridge circuit 22 to the pipe 3, a lead wire 23 connects the bridge circuit 22 to the ring 21, and a display unit 25 is provided outside the pipe 3. The display unit 25 comprises the above-described amplifier 13 and voltmeter 14. The display unit 25 is connected through a lead wire 26 to the bridge circuit 22. A rectifying diode (not shown) is connected to the lead wire 26 in the cylinder member 20.

In this detection system, the static capacitance between the inner wall of the pipe 3 and the ring 21 is employed as the capacitor Cx in Fig. 3, and the electrostatic capacitance is detected to sense a corroded portion 4 of the pipe.

Rings 27 and 28 are provided at both end portions of the cylinder member 20 as shown in Fig. 5 so as to form a detecting probe 29. Each of the rings 27 and 28 has an outside diameter larger than that of the ring 21 but slightly smaller than the inside diameter of the pipe 3, and is made of an insulating material.

In this system, compressed air is supplied into the pipe in the direction of the arrow Q to move the detecting probe 29 in the direction of the arrow P. When the electrical conductive ring 21 is at a position in the pipe where no corrosion damage exists, the capacitance between the pipe 3 and the ring 21 is constant. However, when the ring 21 confronts the corrosion portion 4 of the pipe 3, the capacitance therebetween is decreased because the distance between the ring 21 and the pipe 4 is increased. Therefore, if the pipe 3 and the ring 21 are employed respectively as the electrodes 1 and 2 forming one arm of the bridge circuit 10 (Fig. 3), the degree of corrosion damage can be detected according to the above-described principle. Thus, if the relationships between the degree of corrosion damage and the output voltages of the bridge circuit 22 are obtained from corroded pipes, then the degree of corrosion damage can be detected from the reading of the display unit (voltmeter). The arrangement of the detecting element can be simplified by detecting the capacitance between the pipe 3 and the ring 21 in a manner as described above.

In practice, it is unnecessary to connect the pipe 3 and the bridge circuit 22 with the lead wire 24. If a portion of the cylinder member 20 where the ring 21 is not included is covered by a shielding material 20A, then a constant stray capacitance Co is provided between the shielding material 20A and the pipe 3, as a result of which a series circuit of the capacitors Cx and Co

$$\left(C = \frac{Co\ Cx}{Co + Cx}\right)$$

is formed as shown in Fig. 6(B). Therefore, if the bridge circuit is formed with the series circuit, the degree of corrosion damage can be measured according to the above-described principle.

On the other hand, if a more simplified resonance circuit 30 including the capacitor formed by the ring 21 and the pipe 3 is formed instead of the above-described bridge circuit 22, disestablishment of the resonance state thereof. One example of the resonance circuit is shown in

Fig. 7, which illustrates a primary coil L_3 connected to a high frequency oscillator 11, and a secondary coil L_4 which is electromagnetically coupled to the primary coil L_3. The resonance circuit 30 is made up of these coils L_3 and L_4 and the aforementioned capacitor Cx. In this case, the resonance voltage is picked up from the centre tap of the secondary coil L_4 and is rectified by a diode 12. The resonance voltage thus rectified is applied through an amplifier 13 to a voltmeter 14, where it is indicated. The resonance circuit 30 and the diode 12 are incorporated in the cylinder member 20. If the oscillator 11 is fabricated in the form of an integrated circuit, it can be built in the cylinder member 20. In this case, therefore, it is unnecessary to use a coaxial cable as the lead wire extended into the pipe 3, and accordingly a stable detection can be performed. If the resonance circuit 30 is so adjusted that the maximum resonance voltage is obtained when it is at the normal position (I) in Fig. 1, then when it is at the position (II) where the pipe is corroded, the resonance relation is disestablished because of the variation of the capacitance Cx, as a result of which the output voltage is decreased. In this case, the amount of the output voltage decrease corresponds to the degree of corrosion damage. The degree of corrosion damage can therefore be measured.

In the device described above, one ring 21 is provided in such a manner as to surround the outer wall of the cylinder member 20 forming the detecting probe. Accordingly, sometimes it may not accurately detect a corrosion portion which is locally formed. However, this difficulty can be eliminated by the provision of the following device. In this device, as shown in Fig. 8, a plurality of electrically conductive members 40 to 43 are provided uniformly and symmetrically over the entire surface of the cylinder member, and bridge circuits 44 to 47 are provided for the electrically conductive members 40 to 43, respectively. The outputs of the bridge circuits are converted into DC signals by means of diodes CR_1 to CR_4, respectively, the DC signals being read by respective voltmeters 50. With the device, the state of corrosion damage in the pipe can be positively detected.

If a ring 51 and a bridge circuit which are similar to those described before are provided in addition to the plurality of electrical conductive members 40 to 43 and the plurality of bridge circuits 44 to 47, the station of corrosion damage can be detected, as a whole, by a voltmeter 52.

In the example shown in Fig. 8, the outputs of the bridge circuits are detected by the respective voltmeters. However, in practice, this is unnecessary, and the detection of corrosion portions can be accomplished by detecting the highest out of the outputs of the bridge circuits. In this case, the outputs of the bridge circuits are rectified into DC signals, which are applied to an OR circuit to detect the highest voltage. If the outputs of the bridges are transmitted after being converted into the DC signals in the detecting probe, wiring of the probe can be simplified.

Claims

1. A method of detecting the degree of corrosion damage, in which a member made of an insulating material and having an outside diameter slightly smaller than the inside diameter of a pipe to be inspected is provided, the said member being circular in section and having an electrical conductor mounted on the outer wall thereof, and the said member is moved in the pipe in the longitudinal direction thereof to detect a state of corrosion damage in the inner wall of said pipe from variations in capacitance between the electrical conductor and the pipe which are caused by the movement of the said member in the pipe.

2. A method of detecting the degree of corrosion damage, substantially as herein described with reference to any one of the embodiments shown in Figs. 5 to 8 of the accompanying drawings.

3. A device for detecting the degree of corrosion damage, comprising an electrical conductor provided on a member which is made of an insulating material and is movable in a pipe to be inspected, whereby, in use, variations occur in the static capacitance due to variations in dielectric constant which are caused by the presence and absence of corrosion damage in the pipe as the member is moved in the pipe in the longitudinal direction thereof, the device further comprising a resonance circuit having the said electrical conductor as a component thereof and acting as a detecting circuit.

4. A device as claimed in claim 3, in which a first inductance coil is connected in series to a capacitor formed by the pipe and the electrical conductor, a second inductance coil adapted to excite the first inductance coil is provided between an exciting electric source and the connection point of the capacitor and the first inductance coil, and an output is transmitted through an intermediate tap provided in the first inductance coil.

5. A device for detecting the degree of corrosion damage, comprising an electrical conductor provided on a member which is made of an insulating material and is movable in a pipe to be inspected, a portion of the said member except for the electrical conductor being shielded with a shielding material so that a first capacitor is formed by the pipe and the shielding material and a second capacitor is formed by the pipe and the electrical conductor, the first and second capacitors being used for forming a resonance circuit, so that the presence or absence and degree of corrosion damage in the pipe can be detected from variations of the capacitances of the capacitors which are caused when the said member is moved in the pipe in the longitudinal direction thereof.

6. A device as claimed in claim 5, in which said resonance circuit is formed with a first inductance

coil connected in series to each of the capacitors and a second capacitor provided between an exciting electric source and the connection point of said first inductance coil and each capacitor, and an output is transmitted through an intermediate tap provided in said first inductance coil.

7. A device for detecting the degree of corrosion damage, comprising an inductance coil provided on a member which is made of an insulating material and is movable in a pipe to be inspected, whereby, in use, variations occur in the inductance of said inductance coil due to variations in magnetic permeability which are caused by the presence and absence of corrosion damage in the pipe as the said member moves in the pipe in the longitudinal direction thereof, the device further comprising a resonance circuit having the inductance coil as a component thereof and acting as a detection circuit.

8. A device for detecting the degree of corrosion damage comprising a pair of electrical conductors or a radially extending inductance coil is provided on a member which is made of an insulating material and is movable in a pipe to be inspected, the electrical conductors or inductance coil being built in a detection circuit adapted to serve as an impedance bridge circuit or a resonance circuit, a high frequency voltage being applied, in use, to the detection circuit by an oscillator, and the degree of corrosion damage being detected by moving the said member in the pipe in the longitudinal direction thereof, in which the detection circuit is incorporated in the member and at least one of the said oscillator and an electric source thereof is also incorporated in the said member to form a detecting probe.

9. A device for detecting the degree of corrosion damage, substantially as herein described with reference to any one of the embodiments shown in Figs. 5 to 8 of the accompanying drawings.

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